		Introduction		
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Phase	5200	Task 01		
Job Name	Williams AFB, Site ST012			
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Checked By	JDA	Date 3/17/17		
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Introduction

This package of calculations provides estimates of contaminant mass at ST012 to support remedial action estimates and decisions. The base calculations were updated following the Phase 1 EBR investigation using data into August 2016. Additional characterization data from November and December 2016 was used to update mass extents.

Method:

The overall method includes multiple calculation steps each of which are presented as individual calculations as follows:

1 - Estimate of contaminant mass prior to SEE as the starting point for remedial action

Key Points

a. Assumes that total contaminant mass at ST012 is dominated by LNAPL (dissolved mass is not estimated)

b. Uses historical (pre-SEE) investigations from all areas of ST012 and phase 1 EBR (summer 2016) data from outside the SEE TTZs to estimate the horizontal and vertical extent of areas where there are indications of residual or free phase LNAPL.

c. Assumes that LNAPL predominantly existed at residual conditions prior to SEE. This is suppoted by:

-Although some LNAPL was recovered prior to heating the subsurface, quantities were low and relatively unresponsive to water table depression caused by pumping initiated as part of the containment study.

-Increases in LNAPL recovery in heated areas post SEE reflect a decrease in LNAPL viscosity. LNAPL that may have been at residual concentrations prior to SEE can be mobilized with heating. Mass calculations using literature saturation estimates would be applicable to the pre-SEE (non-heated) state of LNAPL

-Average measured TPH values in LNAPL-impacted areas are less than equivalent TPH values that would be predicted using literature residual saturation values. Estimates are provided using both literature and TPH-based (calculated) residuals but TPH values do not support an average significant mass above residual saturation

d. Includes estimated volumes for each of four general geoloic units (CZ, UWBZ, LPZ, and LSZ). Geologic units were handled as having uniform depths and thickness across the site. Some variation actual depth and thickness is observed in boring logs at different areas of the site.

e. Estimates the volumes within the SEE TTZs and outside the SEE TTZs

f. Because LNAPL migration through the soil likely followed a tortuous path, an assumption of soil conditions being uniformly at resdidual saturation between known LNAPL-impacted locations may overestimate mass. To account for this potential an "uncertainty factor" was applied which provides a lower end estimate.

2 - Estimate the contaminant mass post SEE and pre EBR as a starting point for EBR

Key Points

a. Builds off of the pre-SEE mass estimate (key points above apply)

b. Estimates the mass remaining after SEE based on estimated removal percentages applied to the pre-SEE mass estimate

- Assumes different LNAPL removals in four expanding zones including and around the TTZs (named TTZ, TIZ, ROI, and untreated EBR)

- Because the LPZ was not directly treated, the analysis assumes a lower rate of LNAPL removal in the LPZ based on the footprint of the UWBZ and LSZ above and below the LPZ

c. Compares the predicted mass removal during SEE based on the assumed removal percentages to actual mass removal measured for SEE. For the scenarios that compare closest, the analysis adjusts the assumed mass removal percentages such that the predict mass removal equals the actual mass removal.

d. Estimates the BTEX+Naphthalene mass remaining based on measured LNAPL composition.

3 - Update the estimated contaminant mass post SEE and pre EBR based on addiitonal characterization activities in late 2016

Key Points

a. Estimates the additional volume and LNAPL and BTEX+N associated with three locations of detected LNAPL encountered during the additional characterization.

b. Removal of LNAPL from these areas during SEE is assumed to be negligible based on their distrance from the SEE TTZs

c. Adds the mass/volume from the additional characterization to the mass/volume from the previous calculation.

4 - Estimate the potential amount of TEA required to address remaining COC mass as a starting point

Key Points

a. Estimates made for three TEA technologies: hydrogen peroxide, magnesium sulfate, sodium sulfate

b. Assumed 30% of the TEA demand for total hydrocarbons required as a starting point to achieve BTEX+N removal

Key Acronyms & Definitions:

BTEX+N	benzene, ethylbenzene, toluene, xylenes, and naphthalene
calculated saturation	residual saturation calculated based on an average of TPH concentrations in LNAPL-impacted locations
CZ	cobble zone
COC	contaminant of concern (primarily BTEX+N)
EBR	enhanced bioremediation
literature saturation	residual saturation based on published studies
LNAPL	light non-aqueous phase liquid
LPZ	low permeability zone
LSZ	lower saturated zone
ROI	radius of influence (the zone around the TIZ where limited heating occurred but where LNAPL was likely mobilized to achieve some mass removal)
SEE	steam enhanced extraction
TEA	terminal electron acceptor
TIZ	thermal influence zone (the zone immediate around the TTZ where temperatures were increased but not as high as SEE design temperatures)
TPH	total petroleum hydrocarbons
TTZ	Thermal Treatment Zone (the zone of treatment by SEE where the design tempertures were reached and the highest mass removals occurred.
UWBZ	upper water bearing zone
uncertainty factor	used to develop a range of estimates to account for scenarios where LNAPL-impacted volumes are not 100% at residual saturation as a result of flow channels and tortuous flow paths during LNAPL migration following release

		Pre-SEE mass		
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Purpose: Estimate the volume of residual LNAPL remaining in the thermal treatment zone.

Method:

1 - Estimate volumes of LNAPL contaminated soil in each lithologic unit and within the thermal treatment zone of each lithologic unit .
2 - Calculate pore space volume in each lithologic unit in the thermal treatment zone.
3 - Estimate saturation percentage in each lithologic unit based on TPH analytical data and literature values.
4 - Calculate volume of residual LNAPL.
5 - Estimate the amount of LNAPL that has been removed by previous treatment and natural attenuation.
6 - Calculate the estimated range of remaining residual LNAPL.

Assumptions:

LNAPL contours derived from a review of historical data and the pre-design investigation were used to generate a three dimensional representation (in TecPlot) delineating a volume of soil on site. The volume includes the areas with strong indication of LNAPL presence through recent data (PDI soil testing, well borings from recent remedial action implementation, recent measureable LNAPL in wells, and supported by high dissolved phase groundwater concentrations). This volume is the volume likely to be contributing the most to dissolve phase concentrations above cleanup levels.

The same review was also used to review soil classification data and define the divisions between lithologic units. The TecPlot representation was used to determine the volume of LNAPL contaminated soils within each unit and within the thermal treatment zone.

Porosity of 0.3 for all lithologic units was used to maintain consistency with the Terratherm design assumptions.

Applied NAPL Science Review, Volume 2, Issue 1, January 2012, LCCM Tools: Conversion of TPH in Soils to NAPL Saturation, gives a relationship between TPH and NAPL saturation as follows:

$$S_n = \mathrm{TPH} \cdot \frac{(1-\phi)\cdot \text{Grain Density}\cdot 10^{-6}}{\phi\rho} \quad \text{where } \phi = \text{porosity, and } \rho = \text{LNAPL density}$$

where:

S_n = natural saturation (dimensionless)
TPH = soil total petroleum hydrocarbon contamination (mg/kg)
Φ = soil porosity
ρ = LNAPL density g/cm^3
and grain density is in g/cm^3

Literature values identified in previous BEM modeling efforts for LNAPL saturation of different soil types are also assumed to be valid.

LNAPL is assumed to be at residual saturation. Although some LNAPL accumulates in monitoring wells indicating mobile LNAPL above residual saturation, a condition of residual saturation is likely present for most of the area.

Previous contaminant removal quantities are summarized and sourced in the 2012 FFS, Section 3.4. Only methods impacting soils in the thermal treatment zones were included (the SVE systems were not screened deeply enough to impact the soils in question, and so were not included in the calculation).

In some instances, adjacent soil samples provided analytical results ranging from high concentrations to non-detect and not all borings within the interpreted distribution of LNAPL show strong indicators of LNAPL presence; this suggests that LNAPL distribution is not uniform across the estimated volume of LNAPL contaminated soils and LNAPL volumes estimated assuming uniform distribution of LNAPL within the area may over estimate actual LNAPL volume. . Assumed factors are applied to develop a range to reflect this condition although there is no reliable data to quantitatively estimate this factor.

Constants and Inputs:

2.65	g/cm^3	grain density
0.3	-	total porosity
0.7787	g/cm^3	LNAPL specific gravity (ranges from 0.75 to 0.80 for JP-4)
1%	-	cobble zone LNAPL saturation (no literature value was found matching the cobble zone soil type; an engineer's estimate of 1% was used for the associated LNAPL calculations)
75%	-	assumed low end factor of percent of interpreted LNAPL area actually impacted by LNAPL

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References:

Hawthorne, J. M. & Kirkman, A. J. (2012). LCCM Tools: Conversion of TPH in Soils to NAPL Saturation. *Applied NAPL Science Review, 2*(1).
BEM, 2010, *Final Construction Completion/Inspection Report, Former Williams Air Force Base, Arizona* , prepared for Air Force Center for Engineering and the Environment, Lackland AFB, Texas, May 2010.
AMEC, 2012, *Final Focused Feasibility Study, Remedial Alternatives for Operable Unit 2, Site ST012, Former Williams Air Force Base, Mesa, Arizona* , prepared for the Air Force Civil Engineer Center (AFCEC), Lackland Air Force Base, Texas,
Feenstra et al., 1991. A Method for Assessing Residual NAPL Based on Organic Chemical Concentrations in Soil Samples. *Groundwater Monitoring & Remediation* , 11, 128 – 135

Calculations:

1 - Estimate volumes of LNAPL contaminated soil in each lithologic unit and within the thermal treatment zone of each lithologic unit .

A. Interpret vertical distribution of LNAPL in individual borings for pre-design investigation locations and historical borings (where available)

The following parameters were used based on observations/data for borings for the LNAPL scoring system:

1. If there was a positive dye test within the interval, the interval was automatically scored "Likely Residual LNAPL"
2. If the analytical results for Benzene, Toluene, Ethylbenzene, and Total Xylenes (BTEX) or Naphthalene within the interval showed concentrations indicative of LNAPL based on the methods in Feenstra, et al, 1991, then that interval was automatically scored as "Likely Residual LNAPL"
3. If neither dye test kit results nor BTEX/Naphthalene analytical results indicated the presence of LNAPL or if data was unavailable, the following scoring was used:

Staining:	0 - None, no evidence of LNAPL
	1 - Minimal staining, weak evidence of LNAPL
	2 - Staining or dark staining, strong evidence of LNAPL
Odor:	0 - None, no evidence of LNAPL
	1 - Slight/very slight odor, weak evidence of LNAPL
	2 - Odor, or strong/very strong odor, strong evidence of LNAPL
Dye Test:	0 - None
	4 - LNAPL present
PID:	0 - <45 ppmv, no evidence of LNAPL
	1 - between 45 and 450 ppmv, weak evidence of LNAPL
	2 - > 450 ppmv, strong evidence of LNAPL
Benzene:	0 - less than 20 mg/kg, no evidence of LNAPL
	1 - between 20 and 200 mg/kg, weak evidence of LNAPL
	2 - > 200 mg/kg, strong evidence of LNAPL
TPH (JP-4)	0 - less than 25 mg/kg, no evidence of LNAPL
	1 - between 25 and 250 mg/kg, weak evidence of LNAPL
	2 - > 250 mg/kg, strong evidence of LNAPL

Interpretations were made on 1-foot vertical intervals. Where data for a given parameter was available less frequently, the score from the closest location above was carried down unless there was a technical basis to do otherwise (e.g., significant change in lithologic unit, maximum depth of historical water table, reduction in PID concentration to indicate lack of LNAPL)

The score from all of the factors were summed for each 1-foot interval. Summed values of 6 and greater were considered vertical intervals where current or historical LNAPL presence was likely.

B. Interpretation of LNAPL data to develop LNAPL volumes.

To interpret the extent of LNAPL, the scores for the individual 1-foot intervals were summed for 10-foot intervals. The extent of LNAPL was then contoured manually for each 10-foot interval. The interpretation focused on scores greater than 30 on data from the Pre-Design Investigation borings and well borings from remedial action implementation, additionally informed by areas of measured LNAPL in monitoring wells and with consideration of whether LNAPL presence is supported by dissolved phase concentrations. Contours were extended to include monitoring wells known to have observed LNAPL but lack additional evidence of LNAPL (e.g. boring logs not available). The individual 10-foot contours were entered into the TecPlot analysis. Figures in Appendix B represent the estimated extent of LNAPL. The figures in Appendix B show the treatment zones relative to the LNAPL interpretation footprints for the CZ, UWBZ, and LSZ respectively.

The Tecplot representation was used to determine the volume of LNAPL saturated soils within the lithologic units at the site and within the thermal treatment zones (TTZs).

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	LNAPL Volume Interpretation	
	Total Volume (cu ft)	Volume within TTZ (cu ft)
CZ	455,500	294,250
UWBZ	4,886,000	1,581,500
LPZ*	2,705,000	1,635,375
LSZ	4,695,489	3,879,250

*375 cu ft per LPZ cell, 250 cu ft for all other zones

2 - Calculate pore space volume in each lithologic unit in the thermal treatment zone.

A porosity of 0.3 was used for all lithologic units to remain consistent with the SEE design.

	LNAPL Volume Interpretation	
	Total Pore Space (cu ft)	Pore Space within TTZ (cu
CZ	136,650	88,275
UWBZ	1,465,800	474,450
LPZ	811,500	490,613
LSZ	1,408,647	1,163,775

3 - Estimate saturation percentage in each lithologic unit based on TPH analytical data from PDI and RA well installation and literature values. Observed concentrations calculated by generating an average of multiple sampling locations within each vertical zone for each well to compare with remedial action analytical data.

	Grain Density (g/cc)	LNAPL Density (g/cc)	Average Observed Concentration TPH (mg/kg)	Calculated LNAPL Saturation	Literature Value LNAPL Saturation
CZ	2.65	0.7787	1,760	1.40%	1.00%
UWBZ	2.65	0.7787	4,253	3.38%	4.10%
LPZ	2.65	0.7787	3,565	2.83%	2.80%
LSZ	2.65	0.7787	2,965	2.35%	5.80%

4 - Calculate volume of residual LNAPL.

Total Residual Volume - LNAPL Volume Interpretation

	Total Pore Space (cu ft)	Calculated LNAPL Saturation	Calculated Volume of LNAPL (cu ft)	Literature Value LNAPL Saturation	Literature Volume of LNAPL (cu ft)
CZ	136,650	1.40%	1,910	1.00%	1,367
UWBZ	1,465,800	3.38%	49,502	4.10%	60,098
LPZ	811,500	2.83%	22,972	2.80%	22,722
LSZ	1,408,647	2.35%	33,165	5.80%	81,702
Total	3,822,597		107,549		165,888

Residual Volume within TTZs - LNAPL Volume Interpretation

	Treatment Area Pore Space (cu ft)	Calculated LNAPL Saturation	Calculated Volume of LNAPL (cu ft)	Literature Value LNAPL Saturation	Literature Volume of LNAPL (cu ft)
CZ	88,275	1.40%	1,234	1.00%	883
UWBZ	474,450	3.38%	16,023	4.10%	19,452
LPZ	490,613	2.83%	13,888	2.80%	13,737
LSZ	1,163,775	2.35%	27,400	5.80%	67,499
Total	2,217,113		58,545		101,571

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5 - Estimate the amount of LNAPL that has been removed by pre-SEE treatment and natural attenuation.
See FFS (AMEC, 2012) for basis/references.

	UWBZ (gallons)	LSZ (gallons)	Total (gallons)	
TEE Pilot	9,070	9,070	18,140	(assumed roughly equal in each zone)
Biodegradation	997	4,986	5,980	(100 % LSZ from 1969-1997, then 50/50)
Skimming/Bioslurping	0	10,564	10,564	(primarily removed from LSZ)
Total	10,067	24,620	34,684	

Note: Additional LNAPL mass has been removed from the CZ by the deep soil SVE system but has not been quantified specific to this zone and has not been included in the historical removal estimate.

6 - Calculate the estimated range of pre-SEE treatment remaining residual LNAPL.

An assumed uncertainty factor applied to account for LNAPL distribution being through lenses and stringers rather than continuous throughout the zone. This provides a lower range estimate of volumes. NAPL removal is only applied to volumes using literature residual saturation because calculated residuals already account for NAPL removal via the average TPH values.

Uncertainty factor for treatment volume: 75%
Uncertainty factor for EBR volume: 50%

LNAPL Interpretation

		EBR Treatment Area Volume		Treatment Area Volume		Total Residual Volume	
Vertical Zone	NAPL Parameter	Calculated Volume of LNAPL	Literature Volume of LNAPL	Calculated Volume of LNAPL	Literature Volume of LNAPL	Calculated Volume of LNAPL	Literature Volume of LNAPL
Cobble Zone	cu ft	676	484	1,234	883	1,910	1,367
	gallons	5,057	3,618	9,228	6,603	14,285	10,221
	NAPL Removed (gallons)	0	0	0	0	0	0
	(gallons)	5,057	3,618	9,228	6,603	14,285	10,221
	Uncertainty Factor	50%	50%	75%	75%	66%	66%
	Lower Range (gallons)	2,528	1,809	6,921	4,952	9,449	6,761
Upper Water Bearing Zone	cu ft	33,479	40,645	16,023	19,452	49,502	60,098
	gallons	250,424	304,027	119,851	145,504	370,275	449,532
	NAPL Removed (gallons)	0	0	0	10,067	0	10,067
	(gallons)	250,424	304,027	119,851	135,437	370,275	439,464
	Uncertainty Factor	50%	50%	75%	75%	58%	58%
	Lower Range (gallons)	125,212	152,014	89,888	101,578	215,100	253,591
Low Permeability Zone	cu ft	9,084	8,985	13,888	13,737	22,972	22,722
	gallons	67,946	67,207	103,885	102,754	171,831	169,961
	NAPL Removed (gallons)	0	0	0	0	0	0
	(gallons)	67,946	67,207	103,885	102,754	171,831	169,961
	Uncertainty Factor	50%	50%	75%	75%	65%	65%
	Lower Range (gallons)	33,973	33,603	77,914	77,065	111,887	110,669
Lower Saturated Zone	cu ft	5,765	14,203	27,400	67,499	33,165	81,702
	gallons	43,124	106,235	204,950	504,892	248,074	611,127
	NAPL Removed (gallons)	0	0	0	24,620	0	24,620
	Remaining NAPL	43,124	106,235	204,950	480,272	248,074	586,507
	Uncertainty Factor	50%	50%	75%	75%	71%	70%
	Lower Range (gallons)	21,562	53,118	153,712	360,204	175,274	413,322

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		EBR Treatment Area Volume		Treatment Area Volume		Total Residual Volume	
Vertical Zone	**NAPL Parameter**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**
Cobble Zone and Upper Water Bearing Zone Thermal Treatment Zone	cu ft	38,697	45,622	24,201	27,204	62,898	72,825
	gallons	289,454	341,249	181,021	203,484	470,475	544,733
	NAPL Removed (gallons)	0	0	10,067	10,067	10,067	10,067
	(gallons)	289,454	341,249	170,954	193,417	460,408	534,666
	Uncertainty Factor	50%	50%	75%	75%	59%	59%
	Lower Range (gallons)	144,727	170,625	128,215	145,063	272,942	315,687
Lower Saturated Zone Thermal Treatment Zone	cu ft	10,307	18,695	34,344	74,368	44,651	93,063
	gallons	77,097	139,838	256,892	556,269	333,989	696,108
	NAPL Removed (gallons)	0	0	24,620	24,620	24,620	24,620
	Remaining NAPL (gallons)	77,097	139,838	232,272	531,649	309,369	671,487
	Uncertainty Factor	50%	50%	75%	75%	69%	70%
	Lower Range (gallons)	38,549	69,919	174,204	398,737	212,753	468,656
Cobble Zone, Upper Water Bearing Zone, Low Permeability Zone, and Lower Saturated Zone	cu ft	49,004	64,317	58,545	101,571	107,549	165,888
	gallons	366,551	481,087	437,913	759,753	804,465	1,240,841
	NAPL Removed (gallons)	0	0	34,687	34,687	34,687	34,687
	Remaining NAPL (gallons)	366,551	481,087	403,226	725,066	769,777	1,206,153
	Uncertainty Factor	50%	50%	75%	75%	63%	65%
	Lower Range (gallons)	183,276	240,544	302,419	543,799	485,695	784,343

Conclusion:

Using the literature values that BEM used in previous site modeling during the TEE pilot test and the new interpretations of LNAPL extent, the volume of LNAPL in the thermal treatment zones is estimated to be between 545,000 and 725,000 gallons, leaving between 240,000 and 480,000 gallons in the area outside the thermal treatment zones.

Using the concentrations of TPH in the soil and the equation developed by Hawthorne and Kirkman, the amount of NAPL in the thermal treatment zone is estimated to be between 300,000 and 405,000 gallons, leaving between 185,000 and 365,000 gallons in the area outside the treatment zone.

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Checked By	SCP	Date	12/5/16	

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Purpose: Estimate the volume of residual LNAPL remaining at the Site following SEE treatment.

Method:
1 - Estimate volumes of LNAPL contaminated soil in each lithologic unit and within the thermal treatment zone (TTZ) of each lithologic unit .
2 - Calculate pore space volume in each lithologic unit in the TTZ.
3 - Estimate saturation percentage in each lithologic unit based on TPH analytical data and literature values.
4 - Calculate volume of residual LNAPL.
5 - Estimate the amount of LNAPL that has been removed by previous treatment and natural attenuation.
6 - Calculate the estimated range of remaining residual LNAPL following SEE.
7 - Adjust calculated NAPL concentrations based on Post-SEE NAPL removal

Assumptions:

LNAPL contours derived from a review of historical data and the pre-design investigation were used to generate a three dimensional representation (in TecPlot) delineating a volume of soil on site. The volume includes the areas with strong indication of LNAPL presence through recent data (PDI soil testing, well borings from recent remedial action implementation, recent measureable LNAPL in wells, and supported by high dissolved phase groundwater concentrations). This volume is the volume likely to be contributing the most to dissolve phase concentrations above cleanup levels.

The same review was also used to review soil classification data and define the divisions between lithologic units. The TecPlot representation was used to determine the volume of LNAPL contaminated soils within each unit and within the thermal treatment zone.

Porosity of 0.3 for all lithologic units was used to maintain consistency with the TIZ design assumptions.

Applied NAPL Science Review, Volume 2, Issue 1, January 2012, LCCM Tools: Conversion of TPH in Soils to NAPL Saturation, gives a relationship between TPH and NAPL saturation as follows:

$$S_n = \mathrm{TPH} \cdot \frac{(1-\phi)\cdot \text{Grain Density} \cdot 10^{-6}}{\phi\rho} \quad \text{where } \phi = \text{porosity, and } \rho = \text{LNAPL density}$$

where:
S_n = natural saturation (dimensionless)
TPH = soil total petroleum hydrocarbon contamination (mg/kg)
Φ = soil porosity
ρ = LNAPL density g/cm^3
and grain density is in g/cm^3

Literature values identified in previous BEM modeling efforts for LNAPL saturation of different soil types are also assumed to be valid.

LNAPL is assumed to be at residual saturation. Although some LNAPL accumulates in monitoring wells indicating mobile LNAPL above residual saturation, a condition of residual saturation is likely present for most of the area.

Previous contaminant removal quantities are summarized and sourced in the 2012 FFS, Section 3.4. Only methods impacting soils in the thermal treatment zones were included (the SVE systems were not screened deeply enough to impact the soils in question, and so were not included in the calculation.

In some instances, adjacent soil samples provided analytical results ranging from high concentrations to non-detect and not all borings within the interpreted distribution of LNAPL show strong indicators of LNAPL presence; this suggests that LNAPL distribution is not uniform across the estimated volume of LNAPL contaminated soils and LNAPL volumes estimated assuming uniform distribution of LNAPL within the area may over estimate actual LNAPL volume. . Assumed factors are applied to develop a range to reflect this condition although there is no reliable data to quantitatively estimate this factor.

Assumptions for SEE Treatment by Contour and Zone
The implementation of the SEE system at the site focused treatment on the TTZ for the CZ, UWBZ, and LSZ. The operator indicated that they expected heating (thermal influence zone [TIZ]) to a distance of 10 meters beyond the boundary of the TTZ based on previous experience. The radius of influence of the perimeter extraction wells of the SEE system is expected to extend beyond both the boundary of the TTZ and the TIZ boundary. A distance of 10 meters (20 meters outside of each TTZ) was estimated for the extended radius of influence.

SEE Treatment in the CZ, UWBZ, and LSZ will be assumed to follow the following reductions based on the delineated locations of the TTZ, TIZ and ROI contours. Treatment in the LPZ will be assumed to follow the UWBZ contours on the upper half and LSZ contours on the bottom half of the zone. All LPZ treatment will be assumed the same percentage.

	TTZ	TIZ	ROI	LPZ
% Reduction	90%	60%	30%	30%

Treatment in the LPZ broken down between the UWBZ contours and the LSZ contours. The top half of the LPZ (195 - 202.5 ft bgs) was assumed to be contained in the UWBZ contours, whereas treatment of the bottom half (202.5 - 210 ft bgs) is assumed to be contained within the LSZ contours.

Assumed volatile fraction reduction in each SEE treatment area. The increase in temperature in the TTZ and TIZ is likely to cause a preferential volatilization of light VOCs including benzene. To account for this volatilization, the following volatilization reduction factors were applied to final mass estimates.

	TTZ	TIZ	ROI	Untreated
Volatilization Reduction Factor	90%	25%	0%	0%

Constants and Inputs:

2.65 g/cm^3	grain density
0.3 -	total porosity
0.7787 g/cm^3	LNAPL specific gravity (ranges from 0.75 to 0.80 for JP-4)
1% -	cobble zone LNAPL saturation (no literature value was found matching the cobble zone soil type; an engineer's estimate of 1% was used for the associated LNAPL calculations)

Assumed low end factor of percent of interpreted LNAPL area actually impacted by LNAPL is broken out by treatment zone:

	TTZ	TIZ	ROI	Untreated EBR
Uncertainty Factor	75%	65%	55%	50%

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References:

Hawthorne, J. M. & Kirkman, A. J. (2012). LCCM Tools: Conversion of TPH in Soils to NAPL Saturation. *Applied NAPL Science Review, 2* (1).
BEM, 2010, *Final Construction Completion/Inspection Report, Former Williams Air Force Base, Arizona* , prepared for Air Force Center for Engineering and the Environment, Lackland AFB, Texas, May 2010.
AMEC, 2012, *Final Focused Feasibility Study, Remedial Alternatives for Operable Unit 2, Site ST012, Former Williams Air Force Base, Mesa, Arizona* , prepared for the Air Force Civil Engineer Center (AFCEC), Lackland Air Force Base, Texas, November 2012. [AR# 1535]
Feenstra et al., 1991. A Method for Assessing Residual NAPL Based on Organic Chemical Concentrations in Soil Samples.
Groundwater Monitoring & Remediation , 11, 128 – 135

Calculations:

1 - Estimate volumes of LNAPL contaminated soil in each lithologic unit and within the thermal treatment zone, 10 meters outside of the thermal treatment zone,

A. Interpret vertical distribution of LNAPL in individual borings for pre-design investigation locations and historical borings (where available)

The following scoring interpretations were used based on observations/data for borings:

1. If there was a positive dye test within the interval, the interval was automatically scored "Likely Residual LNAPL"
2. If the analytical results for Benzene, Toluene, Ethylbenzene, and Total Xylenes (BTEX) or Naphthalene within the interval showed concentrations indicative of LNAPL based on the methods in Feenstra, et al, 1991, then that interval was automatically scored as "Likely Residual LNAPL"
3. If neither dye test kit results nor BTEX/Naphthalene analytical results indicated the presence of LNAPL or if data was unavailable, the following scoring was used:

Staining:	0 - None, no evidence of LNAPL
	1 - Minimal staining, weak evidence of LNAPL
	2 - Staining or dark staining, strong evidence of LNAPL
Odor:	0 - None, no evidence of LNAPL
	1 - Slight/very slight odor, weak evidence of LNAPL
	2 - Odor, or strong/very strong odor, strong evidence of LNAPL
Dye Test:	0 - None
	4 - LNAPL present
PID:	0 - <45 ppmv, no evidence of LNAPL
	1 - between 45 and 450 ppmv, weak evidence of LNAPL
	2 - > 450 ppmv, strong evidence of LNAPL
Benzene:	0 - less than 20 mg/kg, no evidence of LNAPL
	1 - between 20 and 200 mg/kg, weak evidence of LNAPL
	2 - > 200 mg/kg, strong evidence of LNAPL
TPH (JP-4)	0 - less than 25 mg/kg, no evidence of LNAPL
	1 - between 25 and 250 mg/kg, weak evidence of LNAPL
	2 - > 250 mg/kg, strong evidence of LNAPL

Interpretations were made on 1-foot vertical intervals. Where data for a given parameter was available less frequently, the score from the closest location above was carried down unless there was a technical basis to do otherwise (e.g., significant change in lithologic unit, maximum depth of historical water table)

The score from all of the factors were summed for each 1-foot interval. Summed values of 6 and greater were considered vertical intervals where current or historical LNAPL presence was likely.

B. Interpretation of LNAPL data to develop LNAPL volumes.

To interpret the extent of LNAPL, the scores for the individual 1-foot intervals were summed for 10-foot intervals. The extent of LNAPL was then contoured manually for each 10-foot interval. Two different interpretations of LNAPL extent were made with the manual contouring. The first interpretation focused on scores greater than 30 on recent data from the Pre-Design Investigation borings and well borings from remedial action implementation, additionally informed by areas of measured LNAPL in monitoring wells and with consideration of whether LNAPL presence is supported by dissolved phase concentrations. This second, more conservative interpretation considered scores greater than 20 for a 10-foot interval representative of LNAPL presence and considered both historical and Pre-Design Investigation locations. Contours were extended to include monitoring wells known to have observed LNAPL but lack additional evidence of LNAPL (e.g. boring logs not available). The individual 10-foot contours were entered into the TecPlot analysis. Figures in Appendix B represent the estimated extent of LNAPL under these two interpretations. The figures in Appendix B show the TTZ and EBR treatment zones relative to the LNAPL interpretation footprints for the CZ, UWBZ, and LSZ respectively.

The implementation of the SEE system at the site focused treatment on the TTZ for the CZ, UWBZ, and LSZ. The operator (TerraTherm) indicated that they expected treatment to a distance of 10 meters beyond the boundary of the TTZ based on previous experience. The radius of influence of the perimeter extraction wells of the SEE system is expected to extend beyond both the boundary of the TTZ and the TIZ boundary. A distance of 10 meters (20 meters outside of each TTZ) was estimated for the extended radius of influence. Tecplot was utilized to estimate the volumes of NAPL within each of the contours. The following volumes were provided based on the TecPlot representation.

In this interpretation the TTZs for SEE were adjusted based on observed in individual wells in each zone based on data collected and summarized as of 05 August 2016. LNAPL present inside the TTZs at this time may represent LNAPL migration from outside the TTZs; however, a conservative approach reduces the size of the TTZ to limit the areas of highest mass removal to locations were LNAPL was not observed.

	LNAPL Volume Interpretation		
	Volume within TTZ (cu ft)	Volume between TTZ and TIZ Contour (cu ft)	Volume between TIZ Contour and ROI Contour (cu ft)
CZ	302,500	68,250	57,500
UWBZ	839,750	737,250	1,883,250
ULPZ	261,375	199,875	483,000
LLPZ	890,250	202,875	274,500
LSZ	2,960,750	695,250	846,500

2 - Calculate pore space volume in each lithologic unit in the thermal treatment zone.

A porosity of 0.3 was used for all lithologic units to remain consistent with the SEE design.

	LNAPL Volume Interpretation		
	Pore Space Within TTZ (cu ft)	Pore Space between TTZ and TIZ Contour (cu ft)	Pore Space between TIZ Contour and ROI Contour (cu ft)
CZ	90,750	20,475	17,250
UWBZ	251,925	221,175	564,975
ULPZ	78,413	59,963	144,900
LLPZ	267,075	60,863	82,350
LSZ	888,225	208,575	253,950

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3 - Estimate saturation percentage in each lithologic unit based on TPH analytical data from PDI and RA well installation and

	Grain Density (g/cc)	LNAPL Density (g/cc)	Average Observed Concentration	Calculated LNAPL Saturation	Literature Value LNAPL Saturation
CZ	2.65	0.7787	1,760	1.40%	1.00%
UWBZ	2.65	0.7787	4,253	3.38%	4.10%
LPZ	2.65	0.7787	3,565	2.83%	2.80%
LSZ	2.65	0.7787	2,965	2.35%	5.80%

4 - Calculate volume of residual LNAPL.

Residual Volume within TTZ contour

	TTZ Pore Space (cu ft)	Calculated LNAPL Saturation	Calculated Volume of LNAPL (cu ft)	Literature Value LNAPL Saturation	Literature Volume of LNAPL (cu ft)
CZ	90,750	1.40%	1,268	1.00%	908
UWBZ	251,925	3.38%	8,508	4.10%	10,329
ULPZ	78,413	2.83%	2,220	2.80%	2,196
LLPZ	267,075	2.83%	7,560	2.80%	7,478
LSZ	888,225	2.35%	20,912	5.80%	51,517
Total	1,576,388		40,468		72,427

Residual Volume between TTZ and TIZ Contour

	Treatment Area Pore Space (cu ft)	Calculated LNAPL Saturation	Calculated Volume of LNAPL (cu ft)	Literature Value LNAPL Saturation	Literature Volume of LNAPL (cu ft)
CZ	20,475	1.40%	286	1.00%	205
UWBZ	221,175	3.38%	7,469	4.10%	9,068
ULPZ	59,963	2.83%	1,697	2.80%	1,679
LLPZ	60,863	2.83%	1,723	2.80%	1,704
LSZ	208,575	2.35%	4,911	5.80%	12,097
Total	571,050		16,087		24,753

Residual Volume between TIZ Contour and ROI Contour

	Total Pore Space (cu ft)	Calculated LNAPL Saturation	Calculated Volume of LNAPL (cu ft)	Literature Value LNAPL Saturation	Literature Volume of LNAPL (cu ft)
CZ	17,250	1.40%	241	1.00%	173
UWBZ	564,975	3.38%	19,080	4.10%	23,164
ULPZ	144,900	2.83%	4,102	2.80%	4,057
LLPZ	82,350	2.83%	2,331	2.80%	2,306
LSZ	253,950	2.35%	5,979	5.80%	14,729
Total	1,063,425		31,733		44,429

Total Residual Volume - LNAPL Volume Interpretation
Numbers taken from Pre-SEE LNAPL Volume Calcs

	Calculated Volume of LNAPL (cu ft)	Literature Volume of LNAPL (cu ft)
CZ	1,910	1,367
UWBZ	49,502	60,098
LPZ	22,972	22,722
LSZ	33,165	81,702
Total	107,549	165,888

5 - Estimate the amount of LNAPL that has been removed by pre-SEE treatment and natural attenuation.
See FFS (AMEC, 2012) for basis/references.

	UWBZ (gallons)	LSZ (gallons)	Total (gallons)	
TEE Pilot	9,070	9,070	18,140	(assumed roughly equal in each zone)
Biodegradation	997	4,986	5,980	(100 % LSZ from 1969-1997, then 50/50)
Skimming/Bioslurping	0	10,564	10,564	(primarily removed from LSZ)
Total	10,067	24,620	34,684	

Note: Additional LNAPL mass has been removed from the CZ by the deep soil SVE system but has not been quantified specific to this zone and has not been included in the historical removal estimate.

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6 - Calculate the estimated range of post-SEE treatment remaining residual LNAPL.

		TTZ Volume		TIZ Contour Volume		ROI Contour Volume		Untreated EBR Volume	
Vertical Zone	**NAPL Parameter**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**
Cobble Zone	cu ft	1,268	908	286	205	241	173	114	82
	gallons	9,487	6,788	2,140	1,532	1,803	1,290	855	611
	Percent Removed	90%	90%	60%	60%	30%	30%	0%	0%
	NAPL Removed	8,538	6,109	1,284	919	541	387	0	0
	Remaining NAPL (gallons)	949	679	856	613	1,262	903	855	611
	Uncertainty Factor	75%	75%	65%	65%	55%	55%	50%	50%
	Lower Range Gallons	7,115	5,091	1,391	995	992	710	427	306
	Lower Range Removed (gallons)	6,403	4,582	835	597	298	213	0	0
	Lower Range Remaining (gallons)	711	509	556	398	694	497	427	306
Upper Water Bearing Zone	cu ft	8,508	8,983	7,469	9,068	19,080	23,164	14,445	18,883
	gallons	63,639	67,193	55,871	67,830	142,718	173,267	108,047	141,242
	Percent Removed	90%	90%	60%	60%	30%	30%	0%	0%
	NAPL Removed	57,275	61,481	33,523	40,698	42,815	51,980	0	0
	Remaining NAPL (gallons)	6,364	5,713	22,348	27,132	99,903	121,287	108,047	141,242
	Uncertainty Factor	75%	75%	65%	65%	55%	55%	50%	50%
	Lower Range Gallons	47,729	50,395	36,316	44,089	78,495	95,297	54,024	70,621
	Lower Range Removed (gallons)	42,956	46,362	21,790	26,454	23,548	28,589	0	0
	Lower Range Remaining (gallons)	4,773	4,033	14,526	17,636	54,946	66,708	54,024	70,621
Upper Low Permeability Zone (All LPZ for Untreated EBR)	cu ft	2,220	2,196	1,697	1,679	4,102	4,057	3,339	3,302
	gallons	16,603	16,423	12,697	12,559	30,682	30,348	24,973	24,701
	Percent Removed	30%	30%	0%	0%	0%	0%	0%	0%
	NAPL Removed	4,981	4,927	0	0	0	0	0	0
	Remaining NAPL (gallons)	11,622	11,496	12,697	12,559	30,682	30,348	24,973	24,701
	Uncertainty Factor	75%	75%	65%	65%	55%	55%	50%	50%
	Lower Range Gallons	12,453	12,317	8,253	8,163	16,875	16,691	12,486	12,350
	Lower Range Removed (gallons)	3,736	3,695	0	0	0	0	0	0
	Lower Range	8,717	8,622	8,253	8,163	16,875	16,691	12,486	12,350
Lower Low Permeability Zone	cu ft	7,560	7,478	1,723	1,704	2,331	2,306	NA	NA
	gallons	56,552	55,936	12,887	12,747	17,437	17,247	NA	NA
	Percent Removed	30%	30%	0%	0%	0%	0%	0%	0%
	NAPL Removed	16,966	16,781	0	0	0	0	0	0
	Remaining NAPL (gallons)	39,586	39,155	12,887	12,747	17,437	17,247	NA	NA
	Uncertainty Factor	75%	75%	65%	65%	55%	55%	NA	NA
	Lower Range Gallons	42,414	41,952	8,377	8,286	9,590	9,486	NA	NA
	Lower Range Removed (gallons)	12,724	12,586	0	0	0	0	NA	NA
	Lower Range Remaining (gallons)	29,690	29,366	8,377	8,286	9,590	9,486	NA	NA
Lower Saturated Zone	cu ft	20,912	48,226	4,911	12,097	5,979	14,729	1,363	6,649
	gallons	131,803	360,727	36,732	90,488	44,723	110,174	10,196	49,738
	Percent Removed	90%	90%	60%	60%	30%	30%	0%	0%
	NAPL Removed	118,623	324,655	22,039	54,293	13,417	33,052	0	0
	Remaining NAPL (gallons)	13,180	36,073	14,693	36,195	31,306	77,122	10,196	49,738
	Uncertainty Factor	75%	75%	65%	65%	55%	55%	50%	50%
	Lower Range Gallons	98,852	270,546	23,876	58,817	24,597	60,596	5,098	24,869
	Lower Range Removed (gallons)	88,967	243,491	14,325	35,290	7,379	18,179	NA	NA
	Lower Range Remaining (gallons)	9,885	27,055	9,550	23,527	17,218	42,417	NA	NA
Cobble Zone and Upper Water Bearing Zone Thermal Treatment Zone	cu ft	11,996	12,086	9,453	10,952	23,423	27,394	16,228	22,267
	gallons	89,729	90,404	70,708	81,920	175,203	204,905	121,388	166,554
	NAPL Removed	70,794	72,517	34,807	41,617	43,356	52,367	0	0
	Remaining NAPL (gallons)	18,935	17,887	35,901	40,303	131,847	152,538	121,388	166,554
	Uncertainty Factor	75%	75%	65%	65%	55%	55%	50%	50%
	Lower Range Gallons	67,297	67,803	45,960	53,248	96,362	112,698	66,937	83,277
	Lower Range Removed (gallons)	53,095	54,639	22,624	27,051	23,846	28,802	0	0
	Lower Range Remaining (gallons)	14,201	13,164	23,336	26,197	72,516	83,896	66,937	83,277

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		TTZ Volume		TIZ Contour Volume		ROI Contour Volume		Untreated EBR Volume	
Vertical Zone	**NAPL Parameter**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**	**Calculated Volume of LNAPL**	**Literature Volume of LNAPL**
Lower Saturated Zone Thermal Treatment Zone	cu ft	28,473	55,704	6,634	13,802	8,310	17,035	3,032	8,301
	gallons	212,975	416,664	49,619	103,235	62,160	127,421	22,682	62,088
	NAPL Removed	135,588	341,435	22,039	54,293	13,417	33,052	0	0
	Remaining NAPL (gallons)	77,387	75,228	27,580	48,942	48,743	94,369	22,682	62,088
	Uncertainty Factor	75%	75%	65%	65%	55%	55%	50%	50%
	Lower Range Gallons	141,266	312,498	32,252	67,103	34,188	70,082	5,098	24,869
	Lower Range Removed (gallons)	101,691	256,077	14,325	35,290	7,379	18,179	NA	NA
	Lower Range Remaining (gallons)	39,575	56,421	17,927	31,813	26,809	51,903	NA	NA
Cobble Zone, Upper Water Bearing Zone, Low Permeability Zone, and Lower Saturated Zone	cu ft	40,468	67,790	16,087	24,753	31,733	44,429	19,261	28,916
	gallons	302,704	507,068	120,327	185,155	237,363	332,326	144,071	216,292
	NAPL Removed	206,382	413,952	56,846	95,910	56,773	85,419	0	0
	Remaining NAPL (gallons)	96,322	93,115	63,481	89,245	180,590	246,907	144,071	216,292
	Uncertainty Factor	75%	75%	65%	65%	55%	55%	50%	50%
	Lower Range Gallons	208,563	380,301	78,213	120,351	130,550	182,779	72,035	108,146
	Lower Range Removed (gallons)	154,787	310,716	36,950	62,341	31,225	46,981	0	0
	Lower Range Remaining (gallons)	53,776	69,585	41,263	58,010	99,324	135,799	72,035	108,146

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7-Adjust calculated NAPL concentrations based on Post-SEE NAPL removal

Actual total removal from SEE implementation based on 29 April 2016 TerraTherm weekly report.
403,092 gallons

Summary of NAPL Volume Predictions (from Step 6)

	Initial Volume	Remaining Volume	Removed Volume	Estimated Removed Volume as a Percentage of Actual Removed Volume
Calculated without Uncertainty Factor	804,465	484,464	320,001	79.4%
Calculated with Uncertainty Factor	489,360	266,399	222,962	55.3%
Literature without Uncertainty Factor	1,240,841	645,560	595,281	147.7%
Literature with Uncertainty Factor	791,577	371,539	420,038	104.2%

Assessment of above scenarios compared to actual removals

Calculated without Uncertainty Factor	Reasonable approximation of actual, adjustment of removal percentages up required to calibrate
Calculated with Uncertainty Factor	Estimated removed volume too low compared to actual removals.
Literature without Uncertainty Factor	Poor approximation of actual, retain in calculations as a worst case approximation.
Literature with Uncertainty Factor	Best approximation of actual, slight adjustment of removal percentages down required to calibrate

The estimations using the literature values for NAPL residuals with uncertainty factor applied provide the best fit to actual removals. This scenario will be used going forward. The estimations using the calculated values for NAPL residuals without uncertainty factor will also be considered as an alternate reasonable approximation. Estimations using the literature values of NAPL residuals without uncertainty factor applied do not fit actual data well but will be retained to represent a worst case estimate. Each of these estimates will be calibrated using actual removals by adjsuting the assumed removal percentages from each zone.

Summary of Pre-EBR Results (to be used for adjustment of assumed removal percentages):
Includes assumption of removal percentages laid out in Assumptions section, not the above removal percentage information based on actual data

Calculated Saturation without Uncertainty Factor

	LNAPL Remaining (gallons)				
	TTZ	TIZ	ROI	Untreated EBR	Total
Calculated					
Cobble Zone	9,487	2,140	1,803	855	14,285
Upper Water Bearing Zone	63,639	55,871	142,718	108,047	370,275
Low Permeability Zone	73,155	25,584	48,119	24,973	171,831
Upper Low Permeability	16,603	12,697	30,682	24,973	
Lower Low Permeability	56,552	12,887	17,437	NA	
Lower Saturated Zone	131,803	36,732	44,723	10,196	223,454
Total	278,084	120,327	237,363	144,071	779,845

Note: the total LNAPL volume remaining varies slightly from those estimated in Appendix A.1 because of changes in the interpreted delineation of the treated volume.

Literature Saturation with Uncertainty Factor

	LNAPL Remaining (gallons)				
	TTZ	TIZ	ROI	Untreated EBR	Total
Literature with Uncertainty Factor Applied					
Cobble Zone	5,091	995	710	306	7,102
Upper Water Bearing Zone	50,395	44,089	95,297	70,621	260,402
Low Permeability Zone	54,269	16,449	26,177	12,350	109,246
Upper Low Permeability	12,317	8,163	16,691	12,350	49,522
Lower Low Permeability	41,952	8,286	9,486	NA	59,724
Lower Saturated Zone	270,546	58,817	60,596	24,869	414,827
Total	380,301	120,351	182,779	108,146	791,577

Note: the total LNAPL volume remaining varies slightly from those estimated in Appendix A.1 because of changes in the interpreted delineation of the treated volume.

Literature without Uncertainty Factor

	LNAPL Remaining (gallons)				
	TTZ	TIZ	ROI	Untreated EBR	Total
Literature					
Cobble Zone	6,788	1,532	1,290	611	10,221
Upper Water Bearing Zone	67,193	67,830	173,267	141,242	449,532
Low Permeability Zone	72,359	25,306	47,595	24,701	169,961
Upper Low Permeability	16,423	12,559	30,348	24,701	84,030
Lower Low Permeability	55,936	12,747	17,247	NA	85,931
Lower Saturated Zone	360,727	90,488	110,174	49,738	611,127
Total	507,068	185,155	332,326	216,292	1,240,841

Note: the total LNAPL volume remaining varies slightly from those estimated in Appendix A.1 because of changes in the interpreted delineation of the treated volume.

Assumed Removal Percentages (reprint from Assumptions section):

	TTZ	TIZ	ROI	LPZ
% Reduction	90%	60%	30%	30%

Adjusted Removal Percentages used to calibrate delineated LNAPL removed using final LNAPL removal mass provided by TerraTherm:

Calculated Saturation without Uncertainty Factor

	TTZ	TIZ	ROI	LPZ
% Reduction	95%	70%	45%	39%

Literature Saturation with Uncertainty Factor Applied

	TTZ	TIZ	ROI	LPZ
% Reduction	80%	60%	35%	26%

Literature without Uncertainty Factor

	TTZ	TIZ	ROI	LPZ
% Reduction	70%	25%	15%	11%

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Checked By	SCP	Date	10/1/2015	
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Checked By	SCP	Date	12/5/16	

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Calculated Saturation without Uncertainty Factor

	LNAPL Removed (gallons)				LNAPL Remaining (gallons)				
	TTZ	TIZ	ROI	Total	TTZ	TIZ	ROI	Untreated EBR	Total
	Calculated Saturation								
Cobble Zone	9,012	1,498	811	11,322	474	642	992	855	2,963
Upper Water Bearing Zone	60,457	39,110	64,223	163,789	3,182	16,761	78,495	108,047	206,485
Low Permeability Zone	28,359	9,918	18,653	56,930	44,797	15,666	29,466	24,973	114,902
Upper Low Permeability	6,436	4,922	11,894	23,252	10,167	7,775	18,788	24,973	61,703
Lower Low Permeability Zone	21,922	4,996	6,760	33,678	34,630	7,892	10,678	NA	
Lower Saturated Zone	125,213	25,712	20,125	171,050	6,590	11,020	24,597	10,196	52,403
Total	223,041	76,238	103,813	403,092	55,043	44,089	133,550	144,071	376,753

Literature Saturation with Uncertainty Factor Applied

	LNAPL Removed (gallons)				LNAPL Remaining (gallons)				
	TTZ	TIZ	ROI	Total	TTZ	TIZ	ROI	Untreated EBR	Total
	Literature Saturation with Uncertainty Factor Applied								
Cobble Zone	4,073	597	248	4,919	1,018	398	461	306	2,183
Upper Water Bearing Zone	40,316	26,454	33,354	100,123	10,079	17,636	61,943	70,621	160,279
Low Permeability Zone	14,067	4,263	6,785	25,115	40,203	12,185	19,392	12,350	84,130
Upper Low Permeability	3,193	2,116	4,326	9,635	9,124	6,047	12,365	12,350	39,887
Lower Low Permeability Zone	10,874	2,148	2,459	15,480	31,078	6,138	7,027	NA	
Lower Saturated Zone	216,436	35,290	21,208	272,935	54,109	23,527	39,387	24,869	141,892
Total	274,892	66,605	61,596	403,092	105,409	53,746	121,183	108,146	388,484

Literature without Uncertainty Factor

	LNAPL Removed (gallons)				LNAPL Remaining (gallons)				
	TTZ	TIZ	ROI	Total	TTZ	TIZ	ROI	Untreated EBR	Total
	Literature Saturation								
Cobble Zone	4,752	383	194	5,328	2,036	1,149	1,097	611	4,893
Upper Water Bearing Zone	47,035	16,957	25,990	89,983	20,158	50,872	147,277	141,242	359,549
Low Permeability Zone	8,032	2,809	5,283	16,124	64,327	22,497	42,312	24,701	153,837
Upper Low Permeability	1,823	1,394	3,369	6,586	14,600	11,165	26,979	24,701	77,444
Lower Low Permeability	6,209	1,415	1,914	9,538	49,727	11,332	15,333	NA	
Lower Saturated Zone	252,509	22,622	16,526	291,657	108,218	67,866	93,648	49,738	319,470
Total	312,328	42,771	47,993	403,092	194,740	142,384	284,333	216,292	837,749

Post-SEE LNAPL Removed and Pre-EBR BTEX+N Remaining using adjusted removal percentages and converted into mass with volatilization reduction factor:

	LNAPL Removed (pounds)				BTEX + N Remaining (pounds)*				
	TTZ	Thermal Influence	ROI	Total	TTZ	Thermal Influence	ROI	Untreated EBR	Total
	Calculated Saturation without Uncertainty Factor Applied								
Cobble Zone	59,211	9,844	5,331	74,386	28	289	595	513	1,425
Upper Water Bearing Zone	397,200	256,950	421,946	1,076,096	191	7,543	47,102	64,835	119,671
Low Permeability Zone	186,316	65,159	122,553	374,028	2,688	7,051	17,681	14,985	42,405
Lower Saturated Zone	822,650	168,929	132,222	1,123,802	610	3,499	11,274	14,985	30,368
Total	1,465,378	500,882	682,052	2,648,312	3,518	18,382	76,652	95,318	193,869
	Literature Saturation with Uncertainty Factor Applied								
Cobble Zone	26,759	3,924	1,632	32,315	61	179	277	183	701
Upper Water Bearing Zone	264,875	173,801	219,135	657,811	605	7,937	37,169	42,377	88,088
Low Permeability Zone	92,417	28,011	44,579	165,007	2,412	5,484	11,636	7,411	26,944
Lower Saturated Zone	1,421,987	231,858	139,339	1,793,185	548	2,722	7,420	7,411	18,100
Total	1,806,039	437,594	404,684	2,648,317	3,626	16,321	56,502	57,382	133,832
	Literature Saturation without Uncertainty Factor Applied								
Cobble Zone	31,218	2,516	1,272	35,006	122	517	658	367	1,664
Upper Water Bearing Zone	309,021	111,411	170,754	591,186	1,210	22,895	88,375	84,754	197,233
Low Permeability Zone	52,769	18,455	34,710	105,934	3,860	10,125	25,390	14,822	54,196
Lower Saturated Zone	1,658,985	148,627	108,576	1,916,188	876	5,025	16,189	14,822	36,912
Total	2,051,994	281,008	315,312	2,648,313	6,068	38,561	130,612	114,765	290,005

*fraction of BTEX+Naphthalene based on LNAPL analysis during SEE. Also assumes volatile fraction reductions of 90% in TTZ and 25% in thermal influence zone.

Benzene Remaining (pounds)

	TTZ	Thermal Influence	ROI	Untreated EBR	Total
	Calculated Saturation				
Cobble Zone	1	12	24	20	57
Upper Water Bearing Zone	8	301	1,879	2,586	4,773
Low Permeability Zone	107	281	705	598	1,691
Lower Saturated Zone	16	198	589	244	1,046
Total	132	791	3,196	3,448	7,568
	Literature Saturation with Uncertainty Factor Applied				
Cobble Zone	2	7	11	7	28
Upper Water Bearing Zone	24	317	1,483	1,690	3,513
Low Permeability Zone	96	219	464	296	1,075
Lower Saturated Zone	22	109	296	296	722
Total	145	651	2,254	2,289	5,338
	Literature Saturation				
Cobble Zone	5	21	26	15	66
Upper Water Bearing Zone	48	913	3,525	3,380	7,867
Low Permeability Zone	154	404	1,013	591	2,162
Lower Saturated Zone	35	200	646	591	1,472
Total	242	1,538	5,209	4,577	11,567

Conclusion: Contaminant mass remaining after SEE implementation was calculated. This method uses the final mass removed, as reported during TerraTherm weekly reports, to determine an adjusted percent removal by zone. Using the adjusted percent removal by zone, the remaining BTEX+N at the site is estimated to be between 134,000 and 194,000 pounds with a worst case scenario of up the 290,000 pounds.

			Add. Char. Update	
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Checked By	JDA	Date	2/6/2017	
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Checked By		Date		

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Purpose: Estimate the additional volume of LNAPL remaining at the Site following SEE treatment based on new information gathered from the Phase 2 site characterization investigation.

Method:
1 - Estimate additional volumes of LNAPL contaminated soil in each area where LNAPL was discovered beyond previously known extents
2 - Calculate pore space volume in each additional area of LNAPL contaminated soil.
3 - Estimate saturation percentage in each area based on TPH analytical data from each area and literature values.
4 - Calculate volume of residual LNAPL.
5 - Assume no previous mass removal from these additional areas.
6 - Calculate the estimated range of remaining residual LNAPL following SEE by addition of these additional areas to the previous estimates

Assumptions:

LNAPL contours derived from a review of historical data and the pre-design investigation were used to generate a three dimensional representation (in TecPlot) delineating a volume of soil on site. The volume includes the areas with strong indication of LNAPL presence through recent data (PDI soil testing, well borings from recent remedial action implementation, recent measureable LNAPL in wells, and supported by high dissolved phase groundwater concentrations). This volume is the volume likely to be contributing the most to dissolve phase concentrations above cleanup levels.

The same review was also used to review soil classification data and define the divisions between lithologic units. The TecPlot representation was used to determine the volume of LNAPL contaminated soils within each unit and within the thermal treatment zone.

Porosity of 0.3 for all lithologic units was used to maintain consistency with the TIZ design assumptions.

Applied NAPL Science Review, Volume 2, Issue 1, January 2012, LCCM Tools: Conversion of TPH in Soils to NAPL Saturation, gives a relationship between TPH and NAPL saturation as follows:

$$S_n = \mathrm{TPH} \cdot \frac{(1-\phi)\cdot \text{Grain Density}\cdot 10^{-6}}{\phi\rho} \quad \text{where } \phi = \text{porosity, and } \rho = \text{LNAPL density}$$

where:
S_n = natural saturation (dimensionless)
TPH = soil total petroleum hydrocarbon contamination (mg/kg)
Φ = soil porosity
ρ = LNAPL density g/cm^3
and grain density is in g/cm^3

Literature values identified in previous BEM modeling efforts for LNAPL saturation of different soil types are also assumed to be valid.

LNAPL is assumed to be at residual saturation. Although some LNAPL accumulates in monitoring wells indicating mobile LNAPL above residual saturation, a condition of residual saturation is likely present for most of the area.

Previous contaminant removal quantities are summarized and sourced in the 2012 FFS, Section 3.4. Only methods impacting soils in the thermal treatment zones were included (the SVE systems were not screened deeply enough to impact the soils in question, and so were not included in the calculation.

In some instances, adjacent soil samples provided analytical results ranging from high concentrations to non-detect and not all borings within the interpreted distribution of LNAPL show strong indicators of LNAPL presence; this suggests that LNAPL distribution is not uniform across the estimated volume of LNAPL contaminated soils and LNAPL volumes estimated assuming uniform distribution of LNAPL within the area may over estimate actual LNAPL volume. . Assumed factors are applied to develop a range to reflect this condition although there is no reliable data to quantitatively estimate this factor.

Constants and Inputs:

2.65	g/cm^3	grain density
0.3	-	total porosity
0.7787	g/cm^3	LNAPL specific gravity (ranges from 0.75 to 0.80 for JP-4)

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Checked By	JDA	Date	2/6/2017	
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References: Hawthorne, J. M. & Kirkman, A. J. (2012). LCCM Tools: Conversion of TPH in Soils to NAPL Saturation. *Applied NAPL Science Review, 2* (1).
BEM, 2010, *Final Construction Completion/Inspection Report, Former Williams Air Force Base, Arizona* , prepared for Air Force Center for Engineering and the Environment, Lackland AFB, Texas, May 2010.
AMEC, 2012, *Final Focused Feasibility Study, Remedial Alternatives for Operable Unit 2, Site ST012, Former Williams Air Force Base, Mesa, Arizona* , prepared for the Air Force Civil Engineer Center (AFCEC), Lackland Air Force Base, Texas, November 2012. [AR# 1535]
Feenstra et al., 1991. A Method for Assessing Residual NAPL Based on Organic Chemical Concentrations in Soil Samples.
Groundwater Monitoring & Remediation , 11, 128 – 135

Calculations: **1 - Estimate additional volumes of LNAPL contaminated soil in each area where LNAPL was discovered beyond previously known extents**

A. Identify Locations of LNAPL Presence

Potential LNAPL presence was identified based on dye test kits during the additional characterization as follows:

1. Soil Boring 18 (SB18) from 205 to 212 feet below ground surface (ft bgs)
2. Soil Boring 19 (SB19) from 215 to 221 ft bgs and from 224 to 225.5 ft bgs.
3. Well LSZ53 from 146 to 150 ft bgs (dye tests were negative for a sample at 169 ft bgs, but a lab sample was collected for verification)

In addition, well LNAPL began to accumulate in well LSZ47 where previously monitoring well analyitical results had suggested LNAPL was not present

Analytical results for soil samples were reviewed to confirm likely LNAPL presence as follows:

1. Soil Boring 18 (SB18) from 205 to 212 feet below ground surface (ft bgs)

Analyte	Units	SB18-205	SB18-210
Diesel Range Organics [C10-C28]	mg/Kg	1,200	1,500
Gasoline Range Organics (GRO)-C6-C10	mg/Kg	7,100	15,000
Benzene	ug/Kg	14,000	14,000

2. Soil Boring 19 (SB19) from 215 to 221 ft bgs and from 224 to 225.5 ft bgs.

Analyte	Units	SB19-35	SB19-215	SB19-219.5	SB19-224
Diesel Range Organics [C10-C28]	mg/Kg	800	140	830	420
Gasoline Range Organics (GRO)-C6-C10	mg/Kg	91	370	580	1,000
Benzene	ug/Kg	<1.6	<1.6	3,900	1,700

3. Well LSZ53 from 146 to 150 ft bgs

Analyte	Units	LSZ53-147	LSZ53-169
Diesel Range Organics [C10-C28]	mg/Kg	4.8	1.4
Gasoline Range Organics (GRO)-C6-C10	mg/Kg	39	13
Benzene	ug/Kg	2.8	630

3. Well LSZ47 from 212 to 215 ft bgs (from EBR well installation program)

Analyte	Units	LSZ47-214
Diesel Range Organics [C10-C28]	mg/Kg	280
Gasoline Range Organics (GRO)-C6-C10	mg/Kg	900
Benzene	ug/Kg	<10,000

Analytical results for SB18, SB19, and LSZ47 confirm NAPL presence detected with dye test kits. Residual LNAPL at LSZ53 is not interpreted to be present for the

1. TPH analytical results show results to be below the reported detection limit of the dye test kits (500 mg/kg).
2 Calculated groundwater concentration based on equilibrium with soil benzene concentrations would not exceed solubility.
3 Residual NAPL was not detected in the CZ at borings for UWBZ28/LSZ51 and LSZ43 (PID readings were < 150 ppm).

B. Interpretation of addition LNAPL impact areas to develop LNAPL volumes.

The location of additional LNAPL detections were compared to the previous interpretations of LNAPL extent for the specific depth interval. LNAPL extents were revised and the additional footprint areas of the resised LNAPL extent was measured. These areas were multiplied be the LNAPL contaminated depth interval to determine the applicable additional volume.

1. SB18 (205-212 ft bgs)
   - Additional footpring of LNAPL residual compared to previous estimate: 23,300 ft^2
   - Vertical interval of LNAPL residual: 7 ft
   - Volume of additional soil with residual LNAPL: 163,100 ft^3
2. SB19 (215-221 ft bgs)
   - Additional footpring of LNAPL residual compared to previous estimate: 9,200 ft^2
   - Vertical interval of LNAPL residual: 6 ft
   - Volume of additional soil with residual LNAPL: 55,200 ft^3
3. SB19 (224-225.5 ft bgs)
   - Additional footpring of LNAPL residual compared to previous estimate: 5,400 ft^2
   - Vertical interval of LNAPL residual: 2 ft
   - Volume of additional soil with residual LNAPL: 8,100 ft^3
4. LSZ47 (212-215 ft bgs)
   - Additional footpring of LNAPL residual compared to previous estimate: 9,000 ft^2
   - Vertical interval of LNAPL residual: 3 ft
   - Volume of additional soil with residual LNAPL: 27,000 ft^3

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2 - Calculate pore space volume in each additional area of LNAPL contaminated soil.

A porosity of 0.3 was used for all lithologic units to remain consistent with the SEE design.

1. SB18 (205-212 ft bgs)
   Volume of additional soil with residual LNAPL 48,930 ft^3
2. SB19 (215-221 ft bgs)
   Volume of additional soil with residual LNAPL 16,560 ft^3
3. SB19 (224-225.5 ft bgs)
   Volume of additional soil with residual LNAPL 2,430 ft^3
4. LSZ47 (212-214 ft bgs)
   Volume of additional soil with residual LNAPL 8,100 ft^3

3 - Estimate saturation percentage in each area based on TPH analytical data from each area and literature values.

	Grain Density (g/cc)	LNAPL Density (g/cc)	Average Observed Average TPH	Calculated LNAPL Saturation	Literature Value LNAPL Saturation
SB18(205-212ftbgs)	2.65	0.7787	12,400	9.85%	5.80%
SB19(215-221ftbgs)	2.65	0.7787	960	0.76%	5.80%
SB19(224-225.5ftbgs)	2.65	0.7787	1,420	1.13%	5.80%
LSZ47(212-214ftbgs)	2.65	0.7787	1,180	0.94%	5.80%

4 - Calculate volume of residual LNAPL.

	Total Pore Space (cu ft)	Calculated LNAPL Saturation	Calculated Volume of LNAPL (cu ft)	Literature Value LNAPL Saturation	Literature Volume of LNAPL (cu ft)
SB18(205-212ftbgs)	48,930	9.85%	4,818	5.80%	2,838
SB19(215-221ftbgs)	16,560	0.76%	126	5.80%	960
SB19(224-225.5ftbgs)	2,430	1.13%	27	5.80%	141
LSZ47(212-214ftbgs)	8,100	0.94%	76	5.80%	470
Total			5,047		4,409

5 - Assume no previous mass removal from these additional areas.

No previous mass removal assumed for these additional areas on the basis that these areas are beyond the TTZs and the TPH data was collected post SEE.

Convert above volumes to gallons and assign to LPZ or LSZ

	Calculated Saturation Volume of LNAPL (gallons)	Calculated Saturation Volume of LNAPL in CZ (gallons)	Calculated Saturation Volume of LNAPL in LPZ (gallons)	Calculated Saturation Volume of LNAPL in LSZ	Literature Volume of LNAPL (gallons)	Literature Saturation Volume of LNAPL in CZ (gallons)	Literature Saturation Volume of LNAPL in LPZ (gallons)	Literature Saturation Volume of LNAPL in LSZ
SB18(205-212ftbgs)	36,037	0	25,741	10,296	21,228	0	15,163	6,065
SB19(215-221ftbgs)	944	0	0	944	7,184	0	0	7,184
SB19(224-225.5ftbgs)	205	0	0	205	1,054	0	0	1,054
LSZ47(212-214ftbgs)	568	0	0	568	3,514	0	0	3,514
Total	37,754	0	25,741	12,013	32,981	0	15,163	17,818

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Calculated Saturation without Uncertainty Factor

	LNAPL Remaining (gallons)						
	TTZ	TIZ	ROI	Untreated EBR	Total	Add Phase 2 Char.	Rev. Total
Calculated Saturation							
Cobble Zone	474	642	992	855	2,963	0	2,963
Upper Water Bearing Zone	3,182	16,761	78,495	108,047	206,485	0	206,485
Low Permeability Zone	44,797	15,666	29,466	24,973	114,902	25,741	140,642
Upper Low Permeability	10,167	7,775	18,788	24,973	61,703	0	61,703
Lower Low Permeability Zone	34,630	7,892	10,678	NA	0	25,741	25,741
Lower Saturated Zone	6,590	11,020	24,597	10,196	52,403	12,013	64,416
Total	55,043	44,089	133,550	144,071	376,753	37,754	414,507

Literature Saturation with Uncertainty Factor Applied (uncertainty factor not applied to additional areas added)

	LNAPL Remaining (gallons)						
	TTZ	TIZ	ROI	Untreated EBR	Total	Add Phase 2 Char.	Rev. Total
Literature Saturation with Uncertainty Factor Applied							
Cobble Zone	1,018	398	461	306	2,183	0	2,183
Upper Water Bearing Zone	10,079	17,636	61,943	70,621	160,279	0	160,279
Low Permeability Zone	40,203	12,185	19,392	12,350	84,130	15,163	99,293
Upper Low Permeability	9,124	6,047	12,365	12,350	39,887	0	39,887
Lower Low Permeability Zone	31,078	6,138	7,027	NA	0	15,163	15,163
Lower Saturated Zone	54,109	23,527	39,387	24,869	141,892	17,818	159,710
Total	105,409	53,746	121,183	108,146	388,484	32,981	421,465

Literature without Uncertainty Factor

	LNAPL Remaining (gallons)						
	TTZ	TIZ	ROI	Untreated EBR	Total	Add Phase 2 Char.	Rev. Total
Literature Saturation							
Cobble Zone	2,036	1,149	1,097	611	4,893	0	4,893
Upper Water Bearing Zone	20,158	50,872	147,277	141,242	359,549	0	359,549
Low Permeability Zone	64,327	22,497	42,312	24,701	153,837	15,163	168,999
Upper Low Permeability	14,600	11,165	26,979	24,701	77,444	0	77,444
Lower Low Permeability	49,727	11,332	15,333	NA	0	15,163	15,163
Lower Saturated Zone	108,218	67,866	93,648	49,738	319,470	17,818	337,288
Total	194,740	142,384	284,333	216,292	837,749	32,981	870,729

Pre-EBR BTEX+N Remaining using adjusted removal percentages and converted into mass with volatilization reduction factor:

	BTEX + N Remaining (pounds)*						
	TTZ	Thermal Influence	ROI	Untreated EBR	Subtotal	Add Phase 2 Char.	Rev. Total
Calculated Saturation without Uncertainty Factor Applied							
Cobble Zone	28	289	595	513	1,425	0	1,425
Upper Water Bearing Zone	191	7,543	47,102	64,835	119,671	0	119,671
Low Permeability Zone	2,688	7,051	17,681	14,985	42,405	15,446	57,851
Lower Saturated Zone	610	3,499	11,274	14,985	30,368	7,209	37,577
Total	3,518	18,382	21,899	95,318	193,869	22,655	216,524
Literature Saturation with Uncertainty Factor Applied							
Cobble Zone	61	179	277	183	701	0	701
Upper Water Bearing Zone	605	7,937	37,169	42,377	88,088	0	88,088
Low Permeability Zone	2,412	5,484	11,636	7,411	26,944	9,099	36,042
Lower Saturated Zone	548	2,722	7,420	7,411	18,100	10,692	28,791
Total	3,626	16,321	19,947	57,382	133,832	19,790	153,622
Literature Saturation without Uncertainty Factor Applied							
Cobble Zone	122	517	658	367	1,664	0	1,664
Upper Water Bearing Zone	1,210	22,895	88,375	84,754	197,233	0	197,233
Low Permeability Zone	3,860	10,125	25,390	14,822	54,196	9,099	63,295
Lower Saturated Zone	876	5,025	16,189	14,822	36,912	10,692	47,604
Total	6,068	38,561	44,629	114,765	290,005	19,790	309,795

*fraction of BTEX+Naphthalene based on LNAPL analysis during SEE. Also assumes volatile fraction reductions of 90% in TTZ and 25% in thermal influence zone.

Benzene Remaining (pounds)

	TTZ	Thermal Influence	ROI	Untreated EBR	Total	Add Phase 2 Char.	Rev. Total
Calculated Saturation							
Cobble Zone	1	12	24	20	57	0	57
Upper Water Bearing Zone	8	301	1,879	2,586	4,773	0	4,773
Low Permeability Zone	107	281	705	598	1,691	616	2,307
Lower Saturated Zone	16	198	589	244	1,046	288	1,334
Total	132	791	3,196	3,448	7,568	904	8,471
Literature Saturation with Uncertainty Factor Applied							
Cobble Zone	2	7	11	7	28	0	28
Upper Water Bearing Zone	24	317	1,483	1,690	3,513	0	3,513
Low Permeability Zone	96	219	464	296	1,075	363	1,438
Lower Saturated Zone	22	109	296	296	722	426	1,148
Total	145	651	2,254	2,289	5,338	789	6,127
Literature Saturation							
Cobble Zone	5	21	26	15	66	0	66
Upper Water Bearing Zone	48	913	3,525	3,380	7,867	0	7,867
Low Permeability Zone	154	404	1,013	591	2,162	363	2,525
Lower Saturated Zone	35	200	646	591	1,472	426	1,899
Total	242	1,538	5,209	4,577	11,567	789	12,356

Conclusion: Contaminant mass remaining after SEE implementation was updated to include additional areas identified. The remaining BTEX+N at the site is estimated to be between 160,000 and 217,000 pounds with a worst case scenario of up the 316,000 pounds.

TEA Estimate

Job No.	9101110001	Sheet	1	of	1
Phase	5200	Task	01		
Job Name	Williams AFB, Site ST012				
By	JDA	Date	9/30/15		
Checked By	SCP	Date	10/1/2015		
Revision 1		Date			
Checked By		Date			

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Purpose: Estimate Stoichiometric Requirements for Terminal Electron Acceptors using LNAPL estimates adjusted to actual SEE results.

Method: Multiply estimated LNAPL mass by stoichiometric requirements.

Assumptions: Ratio of Nutrient to NAPL (from US EPA 1998):

Sulfate	5 lb SO_4^{2-}/lb TPH
Oxygen	3.5 lb O_2/lb TPH
H_2O_2 Solution Concentration	32%

Constants and Inputs: 6.57 lbs of JP-4 per gallon

Molecular Weights (g/mol)

31.98	O_2
96.06	SO_4^{2-}
142.04	Na_2SO_4 anhydrous
246.47	$MgSO_4$ heptahydrate
34.01	H_2O_2

References: USEPA, 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water. EPA/600/R-98/128, U.S. EPA, Washington, DC.

Calculations:

Considering all zones:

Delineated Extent (Calculated Saturation)	Remaining NAPL gallons	Remaining NAPL pounds	Required Nutrient		
			Hydrogen Peroxide tons	Magnesium Sulfate tons	Sodium Sulfate tons
Cobble Zone	2,963	19,466	113	125	72
Upper Water Bearing Zone	206,485	1,356,609	7,890	8,702	5,015
Low Permeability Zone	140,642	924,020	5,374	5,927	3,416
Lower Saturated Zone	64,416	423,216	2,461	2,715	1,564
Total	414,507	2,723,311	15,838	17,469	10,067
Assumed Fraction Required to treat BTEX+N			30%	30%	30%
Required Amount			4,752	5,241	3,020

Considering CZ, UWBZ, and LSZ only (no LPZ)

Delineated Extent (Calculated Saturation)	Remaining NAPL gallons	Remaining NAPL pounds	Required Nutrient		
			Hydrogen Peroxide tons	Magnesium Sulfate tons	Sodium Sulfate tons
Cobble Zone	2,963	19,466	113	125	72
Upper Water Bearing Zone	206,485	1,356,609	7,890	8,702	5,015
Lower Saturated Zone	64,416	423,216	2,461	2,715	1,564
Total	273,865	1,799,291	10,464	11,542	6,651
Assumed Fraction Required to treat BTEX+N			30%	30%	30%
Required Amount			3,139	3,462	1,995